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7B.2

ON THE IMPACT OF SUPER RESOLUTION WSR-88D DOPPLER RADAR DATA ASSIMILATION ON HIGH RESOLUTION NUMERICAL MODEL FORECASTS

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1. INTRODUCTION

Assimilation of radar velocity and precipitation fields into high-resolution model simulations can improve precipitation forecasts with decreased "spin-up" time and improve short-term simulation of boundary layer winds (Benjamin, 2004 & 2007; Xiao, 2008) which is critical to improving plume transport forecasts. Accurate description of wind and turbulence fields is essential to useful atmospheric transport and dispersion results, and any improvement in the accuracy of these fields will make consequence assessment more valuable during both routine operation as well as potential emergency situations.

During 2008, the United States National Weather Service (NWS) radars implemented a significant upgrade which increased the real-time level II data resolution to 8 times their previous “legacy” resolution, from 1 km range gate and 1.0 degree azimuthal resolution to “super resolution” 250 m range gate and 0.5 degree azimuthal resolution (Fig 1). These radar observations provide reflectivity, velocity and returned power spectra measurements at a range of up to 300 km (460 km for reflectivity) at a frequency of 4-5 minutes and yield up to 13.5 million point observations per level in super-resolution mode. The migration of National Weather Service (NWS) WSR-88D radars to *super resolution* is expected to improve warning lead times by detecting small scale features sooner with increased reliability; however, current operational mesoscale model domains utilize grid spacing several times larger than the *legacy* data resolution, and therefore the added resolution of radar data is not fully exploited.

The assimilation of *super resolution* reflectivity and velocity data into high resolution numerical weather model forecasts where grid spacing is comparable to the radar data resolution is investigated here to determine the impact of the improved data resolution on model predictions.

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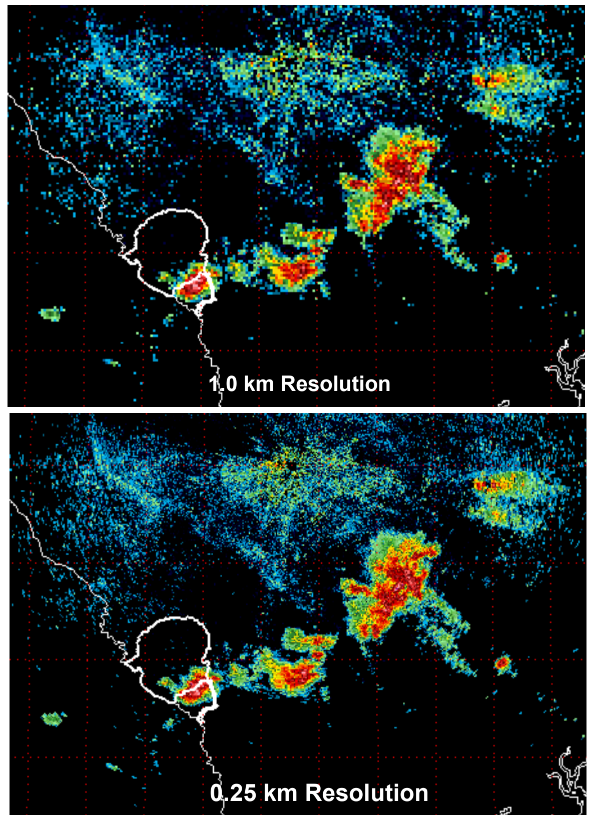

Figure 1. Comparison of *legacy* 1.0 km resolution (top) and *super resolution* 0.25 km resolution (bottom) for Columbia, SC at 00Z August 4, 2008.

2. DOPPLER RADAR ASSIMILATION

Development of software to process NWS Level II radar reflectivity and radial velocity data was undertaken for assimilation of real-time or archived observations into numerical models. In order to prepare the radar observations, a coordinate transformation is performed to convert the radial coordinate data into a volumetric cube. Values are extracted at each point within the cube where data undergo quality control (QC) analysis to eliminate empty / missing data points, decrease anomalous propagation values, and determine error thresholds by utilizing the calculated variances among data values. The Weather Research and Forecasting model (WRF) three dimensional variational data assimilation package (WRF-3DVAR) (Barker et al.,

2004) was used to incorporate the *super resolution* data into the WRF input and boundary conditions by formatting the processed radar profiles into vertical point observations (Xiao, 2008). By comparison to *legacy* resolution, it is clear that the use of *super resolution* data decreases the variance of the radar fields as there is less difference among adjacent data points (Fig 2) which leads to an overall improvement in assimilation weighting.

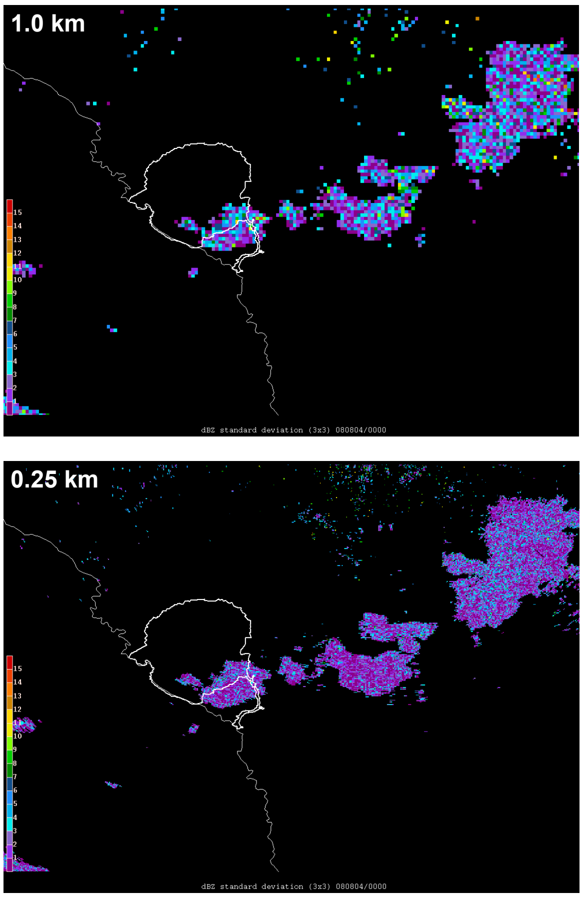

Figure 2. As in Fig 1, except rms difference field computed for assimilation.

3. CASE STUDY – AUGUST 4, 2008

A case study was performed to assess the impact and utility of assimilating *super resolution* radar observations, and to develop a methodology for applying the technique for operational use. The Columbia, South Carolina radar location (KCAE) is the closest WSR-88D site in proximity to the Savannah River Site (SRS) and is approximately 91 km (56 mi) NNE of the center of the site. The KCAE radar was upgraded to *super resolution* on July 23, 2008. On August 3, 2008, shortly after KCAE radar began transmitting *super resolution* observations, a weather event typical of mid-summer late afternoon thundershower activity which frequently affects SRS occurred (as depicted in Fig 1) as a weak, nearly stationary frontal boundary provided a focusing mechanism for convection. The time period beginning 00 UTC (Universal Time Coordinated) August 4, 2008 was chosen for a case study since it presented precipitation conditions in and around SRS at the time of the National Center for Environmental Prediction (NCEP) operational model initialization and could highlight the benefit of radar data assimilation. NCEP's operational 12 km resolution North American Mesoscale (NAM) model

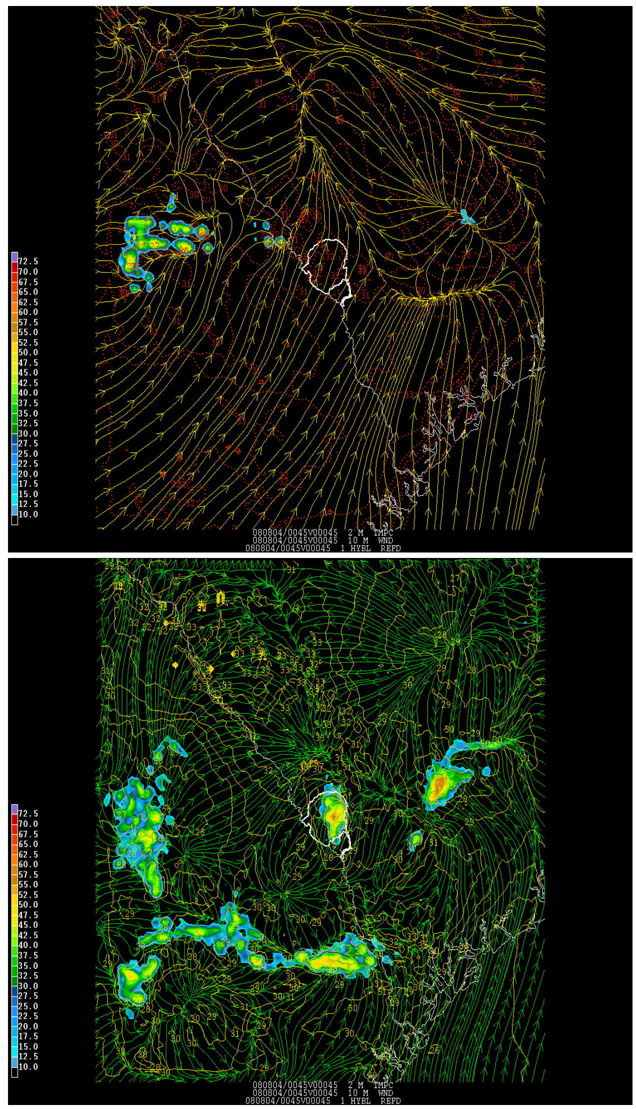

Figure 3. Model simulation of radar reflectivity (shaded areas) and wind streamlines August 4, 2008 00:45 UTC showing base run (Left) and radar assimilation run (Right).

was used to provide the initial and boundary conditions for local higher resolution model runs centered on SRS. A base run utilizing WRF with a 2.5 km grid and a 0.5 km interior nest grid provided the control for comparison with a second run utilizing radar data assimilation from KCAE at the time of model initialization. Additional control runs for three days previous 00Z and 12Z runs (6 runs covering 3 diurnal cycles) were used to generate background error fields for WRF-3DVAR using NCEP's T+24/T-12 method (Barker et al., 2004). Analysis of the model output shows faster spin up to precipitation when radar data is assimilated. By 45 minutes into the model runs, there is little convection in base case, while there is considerable established convection in the radar initialized run. Model output from the radar run shows an established thunderstorm cell over eastern and southeastern SRS (Fig 3).

In order to compare model simulated winds with 15 minute observed wind measurements recorded from SRS meteorological towers, a site average for both 10m above ground level and the lower boundary layer was computed from the instantaneous wind fields generated at each output time of the model runs. Comparison of these fields reveal that the radar assimilation run provides a better agreement during the first 6 hours of simulation, after which, both the assimilation and base runs show little difference due to the dissipation of convective activity and a return to weakly driven nighttime flow (Fig 4).

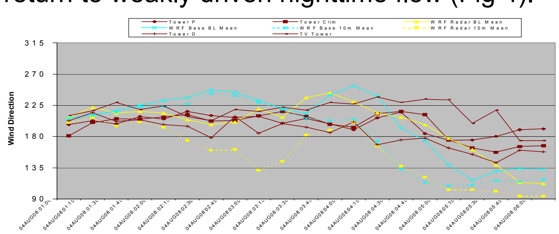

Figure 4. Wind direction from SRS observations (brown), base run (blue) and radar initialized run (yellow) for 0100-0600 UTC August 4, 2008.

The Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) was used to generate atmospheric transport of a hypothetical continuous unit contaminant release (1 Ci hr^{-1}) using forecast wind output for the two model simulations. HYSPLIT has been used in a variety of atmospheric simulation scenarios and has been thoroughly validated against observations (Draxler and Hess, 1997; 1998) and used in a variety of studies (Draxler, 2003; Draxler, 2006; Escudero et al., 2006; and Stein et al., 2007). Turbulence is calculated using the horizontal and vertical velocity variances within the model forecast fields. Surface concentration was calculated assuming effluent within the lowest 50 meters above ground while no removal processes were considered (Fig 5).

The general pattern of both runs is indicative of the larger scale southwesterly transport direction with initial meandering due to the outflow of storms located to the south and west. The primary affect of the generation of convection in the vicinity of SRS prior to 02 UTC in the assimilation case is increased plume spread and slightly lower maximum surface concentrations. The arrival of the cold air pool driven by thunderstorm outflow is seen in both runs between 3Z and 8Z as an abrupt shift to winds from the east as the frontal boundary moves south of SRS. By comparison, the radar assimilation case shows a large area of fumigation which spreads over two-thirds of the SRS site area while the base case shows considerably less areal spread. The period of rapid fumigation occurs coincident with the period where the 10 m and lower boundary layer model wind directions show the greatest differences.

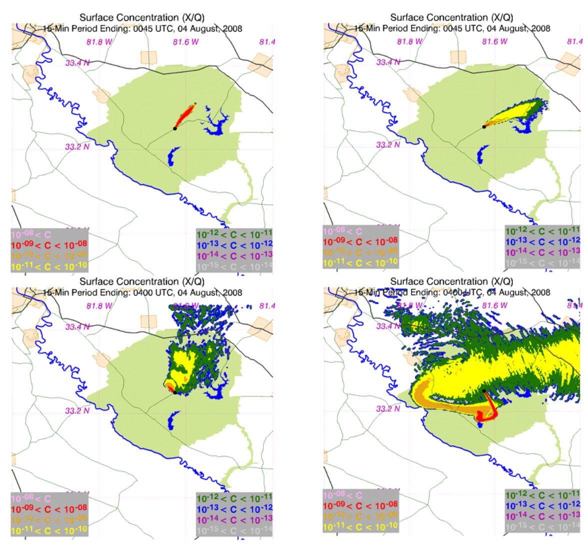

Figure 5. HYSPLIT runs for base case (left) and radar assimilation case (right) depicting concentrations at 45 minutes (top) and 4 hours (bottom) for a simulated release within SRS.

4. CONCLUSIONS:

The spin-up time for precipitation was observed to be less when radar data was assimilated. The lack of observational data in the vicinity of SRS available to NCEP's operational models signifies an important data void where radar observations can provide significant input. These observations greatly enhance the knowledge of storm structures and the environmental conditions which influence their development. The increase in data resolution decreases the root mean squared difference of the radar data fields thereby improving the assimilation weights. The distribution of turbulent mixing also underscores the benefit better precipitation and wind field distribution. As the increase in computational power and availability has made higher resolution real-time model simulations possible, the need to obtain observations to both initialize numerical models and verify their output has become increasingly important. The assimilation of *super resolution* radar observations therefore provides a vital component in the development and utility of these models.

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